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Optical Signal Processing by Silicon Photonics

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Preface

Optical fibre communication is the most promising technology to meet the ever growing need of bandwidth in the present technological era. It not only provides high capacity transmission but also offers flexibility in transportation of data on a network. The major obstacle in further increase in transmission capacity is the use of electronics in signal processing functions and signal amplification. Many researchers and scientists came up with different solutions to eliminate electronics and presented all-optical signal processing techniques. Among these techniques, the use of Self Phase Modulation (SPM), Cross Phase Modulation (XPM), Raman Scattering and Four Wave Mixing (FWM) are well considered but FWM is more attracting due to its inherited benefits. Silicon-on-Insulator (SOI) waveguide devices are emerging to realize any modern optical signal processing scheme. The recent technological improvements in silicon photonics is the main driving force behind the success of these devices. Using nonlinear optical phenomenon in silicon wires and their compatibility with CMOS devices provides the platform for integrated photonic devices. All optical signal processing devices are being investigated and explored at present; however the chip-scale solution provided by silicon photonic is the preferred solution. In this book, the authors have intended to present the summary of their research work in this area. The book focuses on achieving successful optical frequency shifting by Four Wave Mixing (FWM) in silicon-on-insulator (SOI) waveguide by exploiting a nonlinear phenomenon.

This book presents the basic facts, concepts, principles and applications of the nonlinear effects inside the Silicon-on-Insulator waveguide. In this research, in order to achieve optical frequency shifting by FWM in SOI waveguide, a nonlinear phenomenon has been applied successfully. Further, the text is aimed at making graduate students understand the nonlinear effects inside SOI waveguide and possible applications of the latter in this emerging and dominating area of research. The devices manufactured using this technology and the inherent obstacles of the structure faced for some of the fruitful applications are also discussed in this book. The FWM process in SOI waveguides is explained with an emphasis on the effects of two-photon absorption and the consequent free-carrier effects. The optimization of frequency shifting, conversion efficiency and the effect of different parameters on conversion efficiency are also taken into account. Keeping in view the anticipated curiosity of readers, the complete simulation and its subsequent results have explicitly been discussed and demonstrated with illustrating diagrams. It will certainly be more interesting for the readers to know that how the all-optical frequency shifting using single pulsed pump light takes place. The book further encompasses the study of losses due to two photon and free carrier absorption and how to overcome these losses with SOI waveguides.

The book consists of nine chapters in total in which Chap. 1 introduces the subject area along with its significance in the diversified applications.

Chapter 2 describes the research-based past and future trends of the optics. Various research aspects in the area of silica-glass fibre have substantially been explored and pointed out for future trends. This chapter incorporates to a significant extent the current and updated research to offer the foundation for the work that has been done in this field.

Chapter 3 discusses the standards of optical communication and network theory along with their applications and significance in the respective areas. It also examines the characteristics of optical communication systems by discussing different communication media. The devices being used and considered for future consideration are also discussed and summarized for optical networks. Chapter 4 focuses on the gradual and time-needed advancements made in the field of photonics. It also highlights the evolution taken place in the devices which are being used and are being prepared for future trends as well. The traditional and non-traditional motivations regarding selection of silicon as the enabling material for the usefulness of photonics and SOI waveguides are also presented with great emphasis and depth.

Chapter 5 highlights the effects of nonlinearity in optical fibre communication link. Desirable effects of nonlinearity in general and undesirable effects in particular in an optical fibre are enumerated with examples. Cross Phase Modulation (XPM) and high nonlinearity glasses along with their advantages and disadvantages are spelled out with the help of their theories and application in practical systems.

Chapter 6 describes how supercontinuum (SC) sources are replacement of white light sources. Supercontinuum generation in optical fibre, pumped by different sources, which include pumping with femto second (fs), picoseconds (ps) pulse sources and continuous sources are reviewed in this chapter. The nonlinear Schrödinger equation is used to discuss the spectral broadening or SC generation. The chapter also shows that SC generation has been proved very effective and some of its applications are very promising for future ultra-high bandwidth networks.

Chapter 7 provides a theoretical model for pulse propagation inside an SOI waveguide. The Four Wave Mixing (FWM) process in SOI waveguides is discussed with an emphasis on the effects of two-photon absorption and the consequent free-carrier effects. All optical wavelength conversion and optical signal processing along with requisite devices is illustrated with examples exclusively.

In Chap. 8, Four Wave Mixing (FWM) and its types are elaborated in detail. It also describes the mathematical equations which provide basis for mathematical modelling and subsequent realization on various platforms. In order to achieve optical frequency shifting by FWM in silicon-on-insulator (SOI) waveguide, a nonlinear phenomenon has been presented. The FWM process in SOI waveguides is also discussed with an emphasis on the effects of two-photon absorption and the consequent free-carrier effects.

In Chap. 9, in order to achieve optical frequency shifting by FWM in SOI waveguide, a nonlinear phenomenon has been applied successfully by exploiting the Simulink MATLAB® tool. The FWM process in SOI waveguides is the main focus of the work with an emphasis on the effects of two-photon absorption and the consequent free-carrier effects. The optimization of frequency shifting, conversion efficiency and the effects of different parameters on conversion efficiency are also taken into account throughout the time-consuming simulation. The simulated results show the successful all-optical frequency shifting by using signal pulsed pump light and also deal with the losses due to photon absorption and free carrier absorption.The simulated results conclude what numerical values of the different parameters lead to optimal results and how to decrease the undesired losses with SOI waveguide.

In addition to strong understanding of Matlab®, the reader is expected to have prior knowledge of signal processing functions, signal amplifications and familiarization with Self-Phase Modulation, Cross Phase Modulation, Raman Scattering and Four Wave Mixing, etc.

We are highly indebted to our colleagues who extended their cooperation wherever and whenever we looked around, particularly Ms. Menna Nawaz. We appreciate and acknowledge the positive response and forward-looking approach of Dr Ramesh Nath Premnath, Springer Asia throughout our interactions with him. We are reasonably confident in presenting this work, which is the outcome of graduate level research, and hope that it will be a reasonable contribution for the readers in the subject area. However, constructive criticism and suggestions for improvement will warmly be welcomed.

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